

INVASIVE SOFT SCALES (HEMIPTERA: COCCIDAE) AND THEIR THREAT TO U.S. AGRICULTURE

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Abstract.—We provide a compilation of 147 species of soft scales that are considered either pests or represent a threat to United States agriculture. Included for each species, where applicable, is reference to origin and date of introduction if applicable, establishment in the United States, pest or threat status in the United States along with a validation citation, principal hosts, and biogeographical region of origin.

Key Words: Coccidae, soft scales, invasive species, biological control, quarantine, agriculture, forestry, horticulture, ornamentals, fruit trees

Invasive (non-native) species of insects represent an increasing concern to the United States. If non-native species become pests, the consequences include loss of production, diminished product quality, production cost increases, flexibility decreases in production/management decisions, increased risk of human disease, and damaging environmental and aesthetic effects (Huber et al. 2002). Various insects of agricultural concern have been identified as potentially damaging if introduced or reintroduced into the United States (Huber et al. 2002). Invasive species and potentially dangerous species of mealybugs (Pseudococcidae) have been recently examined as they pertain to agriculture in the United States (Miller et al. 2002). The Coccidae or soft scales, like all scale insects, are plant feeders. A few species of soft scales are valuable to man as biological control agents of noxious weeds, however, many are pests of economically important plants.

Because invasive species of insects represent a major concern to U.S. agriculture,

we have investigated several parameters concerning invasive soft scales. Objectives of this paper are: 1) To develop a preliminary world list of the pest soft scales; 2) provide a list of pest soft scales introduced to the continental United States; 3) to determine which species in the previous two objectives are either introduced or native to the continental United States; 3) examine data provided by the United States Department of Agriculture, Animal and Plant Health Inspection Service—Plant Protection and Quarantine (USDA, APHIS-PPQ) concerning the most commonly intercepted soft scales at the United States ports-of-entry; and 5) using all of this information, try to predict which soft scales are the most likely candidates for future invasions into the continental United States.

MATERIALS AND METHODS

Executive Order 13112 established the National Invasive Species Council and provided a definition of an invasive species as "... a species that is 1) non-native (or

alien) to the ecosystem under consideration and 2) whose introduction causes or is likely to cause economic or environmental harm or harm to human health." This definition not only includes species alien to the United States but also encompasses native species. The definition also has an economic or potentially economic component. By this definition, the tulip tree scale, *Toumeyella liriiodendri* (Gmelin), would be an example of an invasive species in the United States even though it likely is native. Our definition is based on Miller et al. (2002) and is more simplistic. They considered invasive species to be those that are non-native [also introduced, nonindigenous, exotic, alien or invasive (Huber et al. 2002)] to the United States regardless of economic harm.

We have used a broad definition of the term "pest" to create a table of pest soft scales of the world (Table 1). If a soft scale is described in the literature as either a pest, causing damage, requiring control, or of economic importance, we have included it in the list. A pest species as defined by some authors (e.g., Ebeling 1959, Pfeiffer 1997) was regarded as any record of a soft scale on certain economic hosts. Ebeling's (1959) justification was based on his consideration that some species not of economic importance become major pests through adaptation or by being transferred to regions of lower environmental resistance. However, Pfeiffer's (1997) inclusion of *Eulecanium lespedezae* Danzig as a pest of deciduous fruit trees is probably an error because the only known host record of this species is *Lespedeza bicolor* Turcz. (Danzig 1986).

Our perspective for this paper has focused on the impact or potential impact of a pest soft scale on agriculture in the contiguous United States. For example, *Ceroplastes psidii* (Chavannes) is known only from *Psidium* spp. Therefore, because guavas are not widely grown in the contiguous United States, it is considered to have relatively minor pest potential in the United States even though it may be far more im-

portant in areas of the world where guava is of greater economic importance. Conversely, *Ceroplastes japonicus* Green, occurs on many different agricultural plants that are economically important in the United States and it is therefore considered a major threat. The term "threat" is used for species that are considered pests but do not occur in the United States. Determination of the date of introduction in the U.S. was established either from literature records or from the oldest collection record in the National Entomological Collection of the National Museum of Natural History, in Beltsville, Maryland. In at least one case (e.g., *Eriopeltis festucae* Boyer de Fonscolombe), the first literature record in the U.S. is Patch (1905) but the oldest collection record is 1899. Obviously, these dates are estimates of the date when a species first invaded the United States.

It is difficult to determine the zoogeographic area of origin for some species. Some distributional records for *Ceroplastes* spp. are from Qin et al. (1998) and *Coccus* spp. are from Gill et al. (1977). It is not always clear whether an invasive species is from the Old or New World. In some cases, we have simply made a supposition based on the current distribution of the species, the distribution of what appears to be its closest relatives, and the natural distribution of its primary host plants. We have used the same criteria to determine if a particular species is native to the United States. Our use of the terms polyphagous, oligophagous, and monophagous has been slightly modified for the current paper and are hereby defined for those species that have greater than 10 host-plant families, 3–10 host-plant families, and 1–2 host-plant families respectively.

RESULTS

Table 1 provides information on 147 species of soft scales. The table includes one species [*Proccoccus acutissimus* (Green)] that has been introduced and established into the United States but is not considered

Table 1. Pest or threat soft scale species to United States agriculture. Abbreviations for origin are Afrotropical Region (AF), Australasian Region (AU), Nearctic (NE), Neotropical Region (NT), Oriental Region (OR), Palearctic Region (PA).

Pest or Threat Species	U.S. Origin and Date of Introduction	Established in U.S.	Pest or Threat Status in U.S.	Reference	Principal Hosts	Origin
<i>Anapalvum pistaciae</i> (Bodenheimer)		no	minor threat	Abu-Yaman 1970	monophagous, including pistachio	PA
<i>Anthococcus keravatae</i> Williams and Watson		no	minor threat	Gill and Kosztarab 1997	oligophagous, including tropical plants	AU
<i>Ceroplastes actiniformis</i> Green		no	threat	Swirski et al. 1997	polyphagous, including tropical fruits	OR
<i>Ceroplastes bergi</i> Cockerell		no	threat	Ebeling 1959	oligophagous, including citrus	NT
<i>Ceroplastes brachyurus</i> Cockerell	native?	yes	minor pest	Gimpel et al. 1974	oligophagous, including citrus and <i>Ilex</i>	NE(?)
<i>Ceroplastes brevicauda</i> Hall		no	threat	Murphy 1997	polyphagous, including coffee and citrus	AF
<i>Ceroplastes ceriferus</i> (Fabricius)	FL, 1908	yes	pest	Gimpel et al. 1974	polyphagous	NT
<i>Ceroplastes cirripediformis</i> Comstock	FL, 1881	yes	pest	Gimpel et al. 1974	polyphagous	NE
<i>Ceroplastes cistudiformis</i> Cockerell	native?	yes	minor pest	Gimpel et al. 1974	polyphagous, including citrus	NE(?)
<i>Ceroplastes destructor</i> Newstead		no	major threat	Sabine 1969	polyphagous, including citrus	AF
<i>Ceroplastes dugesi</i> Lichtenstein	FL, 1908	yes	pest	Hamon and Williams 1984	polyphagous	NT
<i>Ceroplastes eugeniae</i> Hall		no	minor threat	Pfeiffer 1997	oligophagous, including deciduous fruit trees	AF
<i>Ceroplastes floridensis</i> Comstock	FL, 1881	yes	pest	Gimpel et al. 1974	polyphagous, including citrus and ornamentals	NE
<i>Ceroplastes flosculoides</i> Matile-Ferrero		no	minor threat	Matile-Ferrero and Couturier 1993	monophagous, including <i>Marylandia</i>	NT
<i>Ceroplastes grandis</i> Hempel		no	major threat	Gill and Kosztarab 1997	polyphagous, including ornamentals and fruit trees	NT
<i>Ceroplastes japonicus</i> Green		no	major threat	Pellizzari-Scaltriti and Antonucci 1982	polyphagous, including ornamentals	OR
<i>Ceroplastes pseudoceriferus</i> Green		no	major threat	Swirski et al. 1997	polyphagous, including tropical fruits and ornamentals	OR
<i>Ceroplastes psidii</i> (Chavannes)		no	minor threat	Hempel 1920	monophagous, including guava	NT
<i>Ceroplastes quadrilineatus</i> Newstead		no	minor threat	Pfeiffer 1997	oligophagous, including fruit trees	AF
<i>Ceroplastes rubens</i> Maskell	FL, 1955	yes	pest	Gimpel et al. 1974	polyphagous, including citrus and ornamentals	AF

Table 1. Continued.

Pest or Threat Species	U.S. Origin and Date of Introduction	Established in U.S.	Pest or Threat Status in U.S.	Reference	Principal Hosts	Origin
<i>Ceroplastes rusci</i> (Linnaeus)	FL, 1994	yes	pest	Ben-Dov 1988	polyphagous, including citrus and ornamentals	AF
<i>Ceroplastes sinensis</i> Del Guercio	NC, 1920	yes	pest	Gimpel et al. 1974	polyphagous, including citrus and ornamentals	NT
<i>Ceroplastes sinoviae</i> Hall		no	minor threat	Bedford 1968	oligophagous, including ornamentals	AF
<i>Coccus africanus</i> (Newstead)		no	minor threat	Ebeling 1959	oligophagous, including tropical fruits and coffee	AF
<i>Coccus alpinus</i> De Lotto		no	minor threat	Murphy 1997	oligophagous, including tropical fruits and coffee	AF
<i>Coccus celatus</i> De Lotto		no	minor threat	Murphy 1997	polyphagous, including tropical fruits and coffee	AF
<i>Coccus capparidis</i> (Green)	FL, 1975	yes	minor pest	Gill et al. 1977	polyphagous	OR
<i>Coccus discrepans</i> (Green)		no	threat	Ebeling 1959	polyphagous, including tropical fruits	OR
<i>Coccus formicarii</i> (Green)		no	minor threat	Pfeiffer 1997	polyphagous, including tropical fruits	OR
<i>Coccus hesperidum</i> Linnaeus	CA, 1880	yes	pest	Ebeling 1959	polyphagous	OR
<i>Coccus longulus</i> (Douglas)	NY, 1921	yes	major pest	Gill and Kosztarab 1997	polyphagous, including tropical fruits and ornamentals	OR(?)
<i>Coccus pseudoheperidum</i> (Cockerell)	DC, 1912	yes	major pest	Gill and Kosztarab 1997	monophagous, including orchids	NT
<i>Coccus pseudomagnoliarum</i> (Kuwana)	CA, 1910	yes	major pest	Ebeling 1959	oligophagous, including citrus	PA
<i>Coccus viridis</i> (Green)	FL, 1949	yes	major pest	Gill et al. 1977	polyphagous	AF
<i>Coccus watti</i> (Green)		no	threat	Ebeling 1959	monophagous, including citrus and camelia	OR
<i>Cribrlocanium andersoni</i> (Newstead)		no	threat	Brink and Bruwer 1989	oligophagous, including tropical fruits	AF
<i>Crataflostes figi</i> (Maskell)		no	threat	Hosking and Kershaw 1985	monophagous, including beech trees	AU
<i>Didesmococcus koreanus</i> Borchsenius		no	minor threat	Pfeiffer 1997	monophagous, including deciduous fruit trees	PA

Table 1. Continued.

Pest or Threat Species	U.S. Origin and Date of Introduction	Established in U.S.	Pest or Threat Status in U.S.	Reference	Principal Hosts	Origin
<i>Didesmococcus unifasciatus</i> (Archan-gelskaya)		no	threat	Gill and Kosztarab 1997	oligophagous, including decid-uous fruit trees	OR
<i>Drepanococcus chiton</i> (Green)		no	threat	Campbell 1997	polyphagous, including tropi-cal fruits	OR
<i>Ericerus pela</i> (Chavannes)		no	threat	Kosztarab 1997b	monophagous, including decid-uous forest trees	PA
<i>Eriopeltis festucae</i> (Boyer de Fonsco-lombe)	NY, 1899	yes	minor pest	Williams and Kosztarab 1972	monophagous, including grasses	PA
<i>Eucalyptum tessellatus</i> (Signoret)	CA, 1901	yes	major pest	Dekle 1973	polyphagous, greenhouse pest	NT
<i>Eulecanium alnicola</i> Chen		no	minor threat	Pfeiffer 1997	oligophagous, including decid-uous fruit trees	PA
<i>Eulecanium cerasorum</i> (Cockerell)	CA, 1909	yes	major pest	Gill and Kosztarab 1997	oligophagous, including decid-uous forest trees	PA
<i>Eulecanium ciliatum</i> (Douglas)		no	minor threat	Pfeiffer 1997	oligophagous, including decid-uous forest and fruit trees	PA
<i>Eulecanium douglasi</i> (Sulc)		no	threat	Lagowska 1984	oligophagous, including decid-uous forest and fruit trees	PA
<i>Eulecanium kuwoense</i> (Kuwana)	CA, 1896	yes	major pest	McKenzie 1951	oligophagous, including decid-uous fruit trees	PA
<i>Eulecanium novivicum</i> Borchsenius		no	minor threat	Pfeiffer 1997	oligophagous, including decid-uous fruit trees	PA
<i>Eulecanium rugulosum</i> (Archangel-skaya)		no	minor threat	Pfeiffer 1997	oligophagous, including decid-uous fruit trees	PA
<i>Eulecanium sericeum</i> (Lindinger)		no	threat	Kosztarab 1997a	monophagous, including coni-fers	PA
<i>Eulecanium tiliae</i> (Linnaeus)	CA, 1908	yes	major pest	Kosztarab 1996	polyphagous	PA
<i>Eulecanium transcaucasicum</i> Borchsen-ius		no	minor threat	Pfeiffer 1997	monophagous, including decid-uous fruit trees	PA
<i>Filippia follicularis</i> (Targion Tozzetti)		no	minor threat	Gill and Kosztarab 1997	oligophagous, including olive and pistachio	PA
<i>Kilifia acuminata</i> (Signoret)	MO, 1903	yes	pest	Nada et al. 1990	polyphagous	OR
<i>Lichtenia viburni</i> Signoret		no	threat	Gill and Kosztarab 1997	polyphagous, including orna-mentals	PA

Table 1. Continued.

Pest or Threat Species	U.S. Origin and Date of Introduction	Escalated in U.S.	Pest or Threat Status in U.S.	Reference	Principal Hosts	Origin
<i>Maconecus bicruciatu</i> (Green)		no	minor threat	Ebeling 1959	oligophagous, including citrus and mango	OR
<i>Mallosocus viteicola</i> Young		no	minor threat	Wan et al. 1985	oligophagous, including ornamentals and medical herb	PA
<i>Megapalvinaria maxima</i> (Green)		no	threat	Chua 1997b	polyphagous, including tropical plants	OR
<i>Mesolecanium deltae</i> Lizer y Trelles		no	major threat	Teran and Guyot 1969	monophagous, including citrus	NT
<i>Mesolecanium nigrofasciatum</i> (Pergande)	native	yes	major pest	Kosztarab 1996	polyphagous, including fruit trees and ornamentals	NE
<i>Milviscullus mangiferae</i> (Green)	FL, 1935	yes	major pest	Avidov and Harpaz 1969	polyphagous	OR
<i>Miviscullus pilosus</i> Williams and Watson		no	minor threat	Chua 1997a	oligophagous, including coconut	AU
<i>Neolecanium cornuparvum</i> (Thro)	native	yes	minor pest	Williams and Kosztarab 1972	monophagous, including magnolia	NE
<i>Neolecanium silveitri</i> (Hempel)		no	major threat	Lepage and Piza 1941	monophagous, including grapes	NT
<i>Neopulvinaria innumerabilis</i> (Rathvon)	native	yes	major pest	Kosztarab 1997c	polyphagous	NE
<i>Neosaissetia triangularum</i> (Morrison)		no	minor threat	Chua 1997a	monophagous, including coconut	OR
<i>Palaeolecanium bituberculatum</i> (Signoret)		no	major threat	Lagowska 1984	oligophagous, including deciduous fruit trees	PA
<i>Palaeolecanium kosswigi</i> (Bodenheimer)		no	minor threat	Pfeiffer 1997	monophagous, including deciduous fruit trees	PA
<i>Paralecanium cocophyllae</i> Banks		no	minor threat	Chua 1997a	monophagous, including coconut	OR
<i>Paralecanium milleri</i> Takahashi		no	minor threat	Chua 1997a	oligophagous, including mango and coconut	OR
<i>Parasaissetia nigra</i> (Nietner)	AL, 1929	yes	major pest	Gill 1988	polyphagous	OR
<i>Parthenolecanium corni</i> (Bouché)	KS, 1874	yes	major pest	Hamon and Williams 1984	polyphagous	PA
<i>Parthenolecanium fletcheri</i> (Cockerell)	native	yes	pest	Kosztarab 1997a	monophagous, including conifers	NE
<i>Parthenolecanium glandi</i> (Kuwana)		no	minor threat	Pfeiffer 1997	oligophagous, including deciduous fruit trees	PA

Table 1. Continued.

Pest or Threat Species	U.S. Origin and Date of Introduction	Established in U.S.	Pest or Threat Status in U.S.	Reference	Principal Hosts	Origin
<i>Parthenolecanium orientalis</i> Borchsenius		no	minor threat	Pfeiffer 1997	oligophagous, including deciduous fruit trees	PA
<i>Parthenolecanium persicae</i> (Fabricius)	CA, 1897	yes	major pest	Williams and Kosztarab 1972	polyphagous	PA
<i>Parthenolecanium pruinosum</i> (Coullet)	native	yes	major pest	Gill and Kosztarab 1997	oligophagous, including walnuts	NE
<i>Parthenolecanium putnami</i> (Phillips)		no	minor pest	Pfeiffer 1997	oligophagous, including deciduous forest and fruit trees	NE
<i>Parthenolecanium quercifex</i> (Fitch)	native	yes	major pest	Gill 1988	oligophagous, including oaks	NE
<i>Parthenolecanium rufulum</i> (Cockerell)		no	threat	Kosztarab 1997b	polyphagous, including deciduous forest trees	PA
<i>Philephedra broadwayi</i> (Cockerell)		no	threat	Nakahara and Gill 1985	oligophagous, including tropical fruits	NT
<i>Philephedra tuberculosa</i> Nakahara and Gill	native	yes	major pest	Gill and Kosztarab 1997	polyphagous	NE
<i>Physokermes hemicyrphus</i> (Dalman)	CA, 1958	yes	pest	Santias 1988	monophagous, including conifers	PA
<i>Physokermes insignicola</i> (Craw)	native	yes	minor pest	Gill 1988	monophagous, including pines	NE
<i>Physokermes piceae</i> (Schrank)		no	threat	Santias 1988	monophagous, including spruce	PA
<i>Physokermes taxifoliae</i> Coleman	native	yes	pest	Kosztarab 1997a	monophagous, including fir	NE
<i>Platinglistia noacki</i> Cockerell		no	minor threat	Ebeling 1959	polyphagous, including avocado and ornamentals	NT
<i>Platylecanium coccotis</i> Latg		no	minor threat	Chua 1997a	monophagous, including coconut	AU
<i>Proccocus acutissimus</i> (Green)	FL, 1956	yes	not a pest	Gill et al. 1977	polyphagous	OR
<i>Protoperlaria longivalvata</i> Green		no	threat	Ebeling 1959	polyphagous, including tropical fruits and ornamentals	OR
<i>Protoperlaria pyritormis</i> (Cockerell)	FL, 1906	yes	major pest	Del Rivero 1966	polyphagous	NT
<i>Pseudophilippia lanigera</i> (Hempel)		no	minor threat	Ebeling 1959	oligophagous, including citrus	NT
<i>Pseudophilippia quantancu</i> Cockerell	native	yes	pest	Ray and Williams 1980	monophagous, including pines	NE
<i>Pulvinaria acericola</i> (Walsh and Riley)	native	yes	pest	Kosztarab 1997b	oligophagous, including deciduous forest trees	NE
<i>Pulvinaria amygdali</i> Cockerell	native	yes	minor pest	Pfeiffer 1997	monophagous, including deciduous fruit trees	NE

Table 1. Continued.

Pest or Threat Species	U.S. Origin and Date of Introduction	Established in U.S.	Pest or Threat Status in U.S.	Reference	Principal Hosts	Origin
<i>Pulvinaria aurantii</i> Cockerell		no	threat	Gill 1997	polyphagous, including citrus	PA
<i>Pulvinaria citricola</i> Kuwana	MD, 1941	yes	major pest	Gill and Kosztarab 1997	oligophagous, including citrus and persimmon	PA
<i>Pulvinaria decorata</i> Borchsenius		no	minor threat	Ebeling 1959	monophagous, including citrus	AU
<i>Pulvinaria deltoii</i> Gill	CA, 1973	yes	major pest	Gill and Kosztarab 1997	monophagous, including ice-plant	AF
<i>Pulvinaria elongata</i> Newstead	FL, 1927	yes	minor pest	Carnegie 1997	oligophagous, including sugarcane and grasses	NT(?)
<i>Pulvinaria ericicola</i> McConnell	native	yes	pest	Kosztarab 1997b	monophagous, including blueberries	NE
<i>Pulvinaria ficus</i> Hempel		no	threat	Ebeling 1959	polyphagous, including tropical fruits and ornamentals	NT
<i>Pulvinaria flavescens</i> Brethes		no	major threat	Kitayama 1993	oligophagous, including citrus	NT
<i>Pulvinaria floccifera</i> (Westwood)	GA, 1892	yes	pest	Gill and Kosztarab 1997	polyphagous, including citrus and ornamentals	PA(?)
<i>Pulvinaria fujiisana</i> Kanda		no	minor threat	Pfeiffer 1997	monophagous, including deciduous fruit trees	PA
<i>Pulvinaria horii</i> Kuwana		no	minor threat	Pfeiffer 1997	oligophagous, including deciduous forest and fruit trees	PA
<i>Pulvinaria hydrangeae</i> Steinweden		yes	pest	Tondeur et al. 1990	polyphagous, including ornamentals	NE
<i>Pulvinaria iceryi</i> (Signoret)	native	no	minor threat	Carnegie 1997	monophagous, including grasses and sugarcane	AF
<i>Pulvinaria kuwacola</i> Kuwana		no	minor threat	Pfeiffer 1997	oligophagous, including deciduous fruit trees	PA
<i>Pulvinaria maameae</i> Muskell		no	minor threat	Pfeiffer 1997	polyphagous, including tropical fruits	AU
<i>Pulvinaria occidentalis</i> Cockerell	native	yes	minor pest	Pfeiffer 1997	oligophagous, including deciduous fruit trees	NE
<i>Pulvinaria okitsuensis</i> Kuwana		no	minor threat	Ebeling 1959	oligophagous, including citrus and tea	PA
<i>Pulvinaria peninsularis</i> Ferris	native	yes	minor pest	Ebeling 1959	oligophagous, including citrus	NE
<i>Pulvinaria peregrina</i> (Borchsenius)		no	minor threat	Pfeiffer 1997	oligophagous, including deciduous fruit trees	PA

Table 1. Continued.

Pest or Threat Species	U.S. Origin and Introduction	Established in U.S.	Pest or Threat Status in U.S.	Reference	Principal Hosts	Origin
<i>Pulvinaria persicae</i> Newstead		no	minor threat	Pfeiffer 1997	monophagous, including deciduous fruit trees	PA
<i>Pulvinaria phaenae</i> Lull	MA, 1897	yes	minor pest	Gill 1988	monophagous, including orchids	PA(?)
<i>Pulvinaria polygonata</i> Cockerell		no	threat	Gill 1997	oligophagous, including citrus and mango	OR
<i>Pulvinaria pruni</i> Hunter	native	yes	minor pest	Pfeiffer 1997	monophagous, including deciduous fruit trees	NE
<i>Pulvinaria psidii</i> Maskell	FL, 1909	yes	pest	Nada et al. 1990	polyphagous	OR(?)
<i>Pulvinaria regalis</i> Canard		no	major threat	Kozar et al. 1994	polyphagous, including ornamentals	PA
<i>Pulvinaria rhois</i> Ebrhorn	native	yes	minor pest	Pfeiffer 1997	oligophagous, including deciduous fruit trees	NE
<i>Pulvinaria urticae</i> Cockerell	LA, 1925	yes	major pest	Gill and Kosztarab 1997	polyphagous	NT
<i>Pulvinaria vitis</i> (Linnaeus)	NY, 1880	yes	pest	Kosztarab and Kozar 1988	polyphagous	PA
<i>Pulvinariella mesembryanthemi</i> (Vallot)	CA, 1971	yes	pest	Donaldson et al. 1978	monophagous, including succulents	AF
<i>Rhodococcus perornatus</i> (Cockerell and Parrott)		no	minor threat	Ordogh 1995	monophagous, including roses	PA
<i>Rhodococcus samuoni</i> Borchsenius		no	minor threat	Pfeiffer 1997	monophagous, including deciduous fruit trees	PA
<i>Rhodococcus turanicus</i> (Archangel-skaya)		no	threat	Pfeiffer 1997	oligophagous, including deciduous fruit trees	PA
<i>Saccharolecanium krugeri</i> (Zehntner)		no	minor threat	Carnegie 1997	monophagous, including sugar cane	OR
<i>Saissetia citricola</i> (Kuwana)		no	minor threat	Pfeiffer 1997	oligophagous, including citrus and deciduous fruit trees	PA
<i>Saissetia coffeae</i> (Walker)	CA, 1914	yes	pest	Hamon and Williams 1984	polyphagous	NT
<i>Saissetia miranda</i> (Cockerell and Parrott)	FL, 1918	yes	pest	Stauffer and Rose 1997	polyphagous	NE
<i>Saissetia neglecta</i> De Lotto	FL, 1921	yes	pest	Stauffer and Rose 1997	polyphagous	NT
<i>Saissetia oleae</i> (Olivier)	KS, 1905	yes	pest	Bartlett 1978	polyphagous	PA(?)
<i>Saissetia persimilis</i> (Newstead)		no	threat	Pfeiffer 1997	polyphagous, including ornamentals and deciduous fruit trees	AF

Table 1. Continued.

Pest or Threat Species	U.S. Origin and Date of Introduction	Established in U.S.	Pest or Threat Status in U.S.	Reference	Principal Hosts	Origin
<i>Saissetia socialis</i> Hempel		no	minor threat	Pfeiffer 1997	monophagous, including deciduous fruit trees	NT
<i>Saissetia subpatelliforme</i> (Newstead)		no	minor threat	Ebeling 1959	oligophagous, including citrus	AF
<i>Saissetia zanzibarensis</i> Williams		no	minor threat	Chua 1997a	polyphagous, including tropical fruit trees	AF
<i>Sphaerolectanium prunastri</i> (Boyer de Fonscolombe)	P.A. 1895	yes	major pest	Gill and Kosztarab 1997	oligophagous, including fruit trees	PA
<i>Takahashia japonica</i> Cockerell		no	minor threat	Pfeiffer 1997	oligophagous, including ornamentals and deciduous fruit trees	PA
<i>Toumeyella cubensis</i> Heidel and Köhler		no	threat	Gill 1997	monophagous, including citrus	NT
<i>Toumeyella liriodendri</i> (Gmelin)	native	yes	major pest	Burns and Donley 1970	oligophagous, including forest trees	NE
<i>Toumeyella parvicornis</i> (Cockerell)	native	yes	major pest	Rabbin and Lejeune 1955	monophagous, including pines	NE
<i>Toumeyella pini</i> King	native	yes	pest	Clarke et al. 1992	monophagous, including pines	NE
<i>Toumeyella pinicola</i> Ferris	native	yes	major pest	Gill and Kosztarab 1997	monophagous, including pines	NE
<i>Toumeyella virginiana</i> Williams and Kosztarab	native	yes	pest	Kosztarab 1997a	monophagous, including pines	NE
<i>Vinsonia stellifera</i> (Westwood)	FL, 1953	yes	pest	Dekle 1969	polyphagous	OR

Soft Scale Introductions in the U.S.: 1870-1999

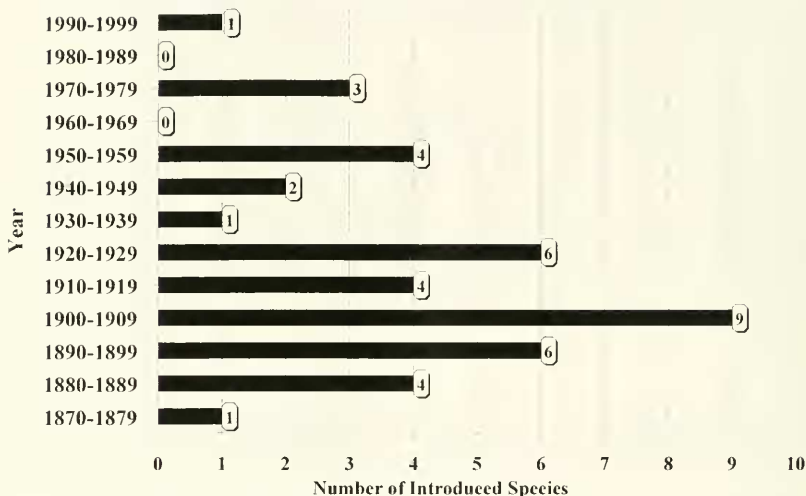


Fig. 1. Soft scale introductions in the United States from 1870–1999.

a pest. Therefore, we estimate that there are 146 species that are either pests or represent threats to U.S. agriculture. Of the 66 soft scales considered pests in the U.S., 25 are either native or possibly native species. Therefore, 41 of the soft-scale pests in the country are invasive. Based on Coccidae information presented in ScaleNet (Ben-Dov 2002), there are 105 species of soft scales in the United States; thus, the invasive component of the soft-scale fauna in the United States is approximately 39%. This percentage is much higher than the 13% of invasive species in the mealybug fauna of the U.S. (Miller et al. 2002). With the exception of the 1960's and the 1980's, at least one species of soft scale (Fig. 1) has been introduced every decade since the 1870's. The greatest number of introduced soft scales (nine species) occurred between 1900 and 1909. Two periods, the 1890's and the 1920's, witnessed the introduction of six species. More than 73% of the invasive soft scales were introduced in the

first 69 years of record keeping (1870–1939).

A summary of the region of origin of all invasive soft scales in the U.S. is as follows: Palearctic Region, 13; Neotropical Region, 11; Oriental Region, 9; Afrotropical Region, 5; Nearctic Region outside of the U.S., 3; and Australasian Region, 0. Of all of these species in the U.S., only *Prococcus acutissimus* (Green) from the Oriental Region is not considered a pest.

Examination of the region of origin for pest soft scales worldwide provides the following results: Palearctic, 46; Nearctic, 29; Oriental, 25; Neotropical, 23; Afrotropical, 18; and Australasian, 6. Host characteristics of these pests include 38% polyphagous, 33% oligophagous, and 29% monophagous. Based on the characteristics of zoogeographic regional distributions of the highest number of soft-scale pests (Palearctic, Neotropical, and Oriental Regions, respectively), and greatest frequency of host plants (polyphagous and oligophagous), a list of

the species most likely to invade the United States was determined. Those species likely to invade from the Palearctic Region include *Eulecanium douglasi* (Šulc), *Lichtenisia viburni* Signoret, *Palaeolecanium biturbulatum* (Signoret), *Parthenolecanium rufulum* (Cockerell), *Pulvinaria aurantii* Cockerell, *Pulvinaria regalis* Canard, and *Rhodococcus turanicus* (Archangelskaya). Those species likely to invade from the Neotropical Region include *Ceroplastes bergi* Cockerell, *Ceroplastes grandis* Hempel, *Philephedra broadwayi* (Cockerell), *Pulvinaria ficus* Hempel, and *Pulvinaria flavescens* Brethes. Those species likely to invade from the Oriental Region include *Ceroplastes actiniformis* Green, *Ceroplastes japonicus* Green, *Ceroplastes pseudoceriferus* Green, *Coccus discrepans* (Green), *Didesmococcus unifasciatus* (Archangelskaya), *Drepanococcus chiton* (Green), *Megapulvinaria maxima* (Green), *Protopulvinaria longivalvata* Green, and *Pulvinaria polygonata* Cockerell.

USDA, APHIS-PPQ records from the past five years also were searched to determine which intercepted species of soft scales pose the greatest threat. A list of the top seven species most frequently intercepted at U.S. ports-of-entry are *Ceroplastes japonicus* Green, *Coccus moestus* De Lotto, *Philephedra broadwayi* (Cockerell), *Protopulvinaria longivalvata* Green, *Pulvinaria polygonata* Cockerell, *Tillancoccus mexicanus* Ben-Dov, and *Udinia catori* (Green). Comparison of the two lists reveals the following four species common to both: *Ceroplastes japonicus*, *Philephedra broadwayi*, *Protopulvinaria longivalvata*, and *Pulvinaria polygonata*. While the possibility exists that other soft scales could invade the U.S., we suggest that the four aforementioned species are the most plausible candidates as the next invasive soft scales into the United States.

DISCUSSION

Our data indicate that the decade starting in 1900 had the largest number of soft scale

insect introductions into the U.S. Although Miller et al. (2002) speculated that high number of mealybug interceptions may be linked to detection strategies and procedures developed in conjunction with the Plant Quarantine Act in 1912, the number of soft scale introductions is not consistent with this hypothesis.

The introduction of even a single species is of concern to U.S. agriculture. Huber et al. (2002) hypothesized that if a pest can enter the United States, over time there is a strong likelihood for establishment. As a result, they believed more appropriate and cost-effective quarantine procedures must be developed. We think one step in this procedure is to identify those species of insects which pose the greatest threat.

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